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RESTORATION OF SHELL PARTS BY THE PAINTED SNAIL, POLYMITA PICTA BORN

BY E. A. ANDREWS

Observation of the shells of snails shows in some cases besides the regular fine lines suggesting lack of uniform growth, occasional grosser breaks in the uniformity of the surface suggesting the healing of broken parts or the restoration of lost parts of the shell.

That snails do actually restore broken parts and heal over breaks in their shells was first demonstrated by the experiments of Reamur in 1709 and later by those of many zoologists from 1870 to 1911. From these experiments it appears that snails may restore the shell in two distinct ways; restoring lost parts at the rim of the shell by complete perfect shell joining on to the normal shell without serious differences in form, structure, or color; but making good insular loss of shell parts not at the rim of the shell by a sort of cicatrix material, hard and serviceable for the protection of the animal within, but very imperfect as compared to the former normal shell.

These two grades of perfection in shell restoration correspond to the two diverse regions of the mantle concerned in shell making; the young marginal part of the mantle being able to make all the outer layers of the shell with its colors and architecture while the older parts of the mantle far from the mantle margin can only add innermost layer to the normal shell or function after breaks to supply a sort of cement to mend the break but not to actually restore new shell in its totality.

Both color and architecture of the shell are due to the activities of the marginal part of the mantle which, as it were, is the die from which the shell is stamped out little by little at the edge as

growth goes on with a repetition of pattern comparable to that made by a printing roll for wallpaper or printed goods; repairs near the edge are actual new printings, but repairs far from the margin are but colorless patching.

The activities of the mantle near the margin are both secretory and muscular, while far from the free edge the mantle only secretes, apparently. The muscular actions of the mantle combined with its powers to make hardening lime shell as well as color in definite patterns is comparable to the like activities in that portion of the oviduct of birds in which the eggshell is formed, sculptured and painted, in the same characteristic way in active periods of the species and even of the individual, as may be seen in the domestic hen which may for some time lay eggs individually distinguishable from those of other members of the same flock.

In some gastropods the mantle is visibly colored somewhat in the pattern of the shell that it makes, the future materials being already assembled in the relative poitions they will occupy when incorporated into the shell. There would thus seem to be a point to point agreement between the mantle margin and its product, the shell.

However, the mantle margin is movable, not only to advance and recede, but apparently also to slip sidewise, since Techow[1] found that in the land snail *Helix pomatia* removal of both a piece of the shell and of the underlying mantle was followed by restoration of the shell sooner than by regrowth of the cut mantle, so that the mantle seemed to have glided to one side and part of it vicariously made an area of the shell that it normally would not have been concerned with.

Many of the experiments upon regeneration in gastropods have been performed upon shells that were rather uniform in color so that one part of the mantle margin had much the same function as adjacent portions. However, in snails with lengthwise color bands, the mantle margin makes sharply localized color effects upon a common ground, so that one locality of the mantle is responsible for a colored band and the adjacent part on either side makes only the common background. Such is notably the case

[1] Techow. Archiv Ent. Mech. 31: 278, 1910.

in the painted snail, *Polymita picta* Born, of Cuba, with its conspicuous lengthwise bands.

Some fifty-four immature snails of the western variety of this species, *P. picta venusta,* brought from Cuba by Mr. d'Alte Welch, each from one to one and a half centimeters in diameter, were used to test the ability of the mantle margin to restore shell of the proper kind to continue the normal pattern after removal of small pieces of the shell edge.

Of these shells 27 were dull white; 17 canary yellow, and 10 flushed with bright red. In general, there were three spiral bands, an upper and a lower dark band and a median band, rarely dark, but generally pale white. Thus the mantle edge was making dark above and below, in narrow regions, and a thin white region in the middle; with wide areas of white, yellow, or red between the three narrow regions.

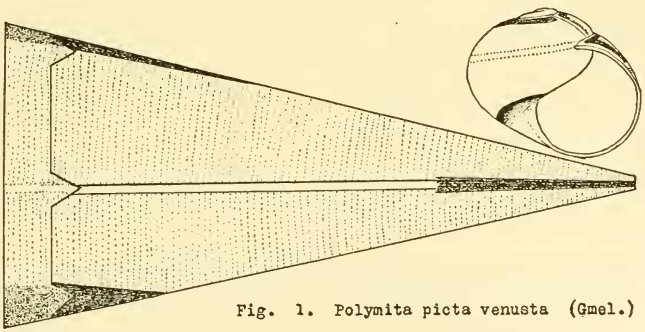

Fig. 1. Polymita picta venusta (Gmel.)

A rough diagram of the shell pattern may be made by representing the shell as unrolled and then projected as a triangle (see Fig. 1) in which the base represents the present mouth of the shell and the apex the long antecedent young shell now located at the apex of the shell. In youth the median band was dark, but later this gave place to a median band that is usually white, while the other two bands, both dark, arose subsequently, the latest and broadest being the ventral band.

In life the mantle margin of these snails is a velvet black zone at the border followed a little back from the edge by a golden yellow zone of white or red so that these two contrasting color zones on the mantle are very striking. In the black zone is the

mantle groove whose outer edge is somewhat lighter than the rest of the black zone and it is in this groove that the new shell is initiated.

The light colored sub-marginal zone may show some striking interruptions; thus when the shell has an equatorial band of light, or of dark, the light sub-marginal zone is marked by a sharp interruption of the same width as the shell band. The light zone is full of minute white reflecting particles and these are absent from the part of the zone immediately under the equatorial shell band, be it white or dark. Also the lighter submarginal zone may show dark patches above and below underlying the dark bands of the shell and in a shell with two parallel equatorial bands, two corresponding brown patches were seen on the mantle.

To see if the mantle would exactly restore the pattern when the shell was locally impaired, triangular areas of the shell, some 4 mm. wide and 2 deep, were cut from the shell with scissors, June 1st (the mantle being withdrawn by the snail so that it was not injured), in the three ends of bands as in Fig. 1 as well as in some of the background regions.

All the snails were kept in a glass jar of six liters capacity with top ventilation and various rather unsuccessful attempts at feeding, so that mortality was great, and in October only five were left alive. Other snails of the same species died as rapidly, though nothing was done to injure the shells.

However, many of the snails restored the regions of the shell that were removed. Some new shell with a bit of color in the right place was evident within a week in some snails, but others delayed so that at any time many were in various stages of restoration of injuries to the shells. Thirty-eight snails were living July 5 and eleven days later many had quite filled in the notches cut in the shells and some had extended the shell out beyond the old rim; but many never restored the shell injury before dying.

Restoration took place in the following stages: first a soft pellicle stretched as by surface tension across the deepest part of the triangular space, then extending gradually outward across more and more of the triangle. This soft pellicle stiffened and though at first at transparent as the evanescent pellicle that

anchors the shell to the substrate when the snail is long at rest, it became more opaque till when one to two millimeters advanced in width there was seen upon its under surface a little white, yellow or red pigment. After a long period this deposit became an opaque shell underlying the first formed periostracum.

As this colored opaque area increased, it was evident that it became the right color to replace what was removed; yellow joined onto yellow, white onto white, red onto red. But for a long time the new shell was thinner than the normal, less opaque, and lacking in perfection of finish, showing more evident lines of growth. Where the new joins the old, there is generally a faulting in the surface since the new is not built quite out to the level of the old surface. The first half millimeter or so of background shell sometimes remained lacking in opaqueness and in color, leaving a permanent scar. These experiments indicate that the mantle is able to reenact its old performances making for each area the proper color to continue the pattern laid down on the old shell.

Microscopic examination of the mantle margin after three days of regenerative activity showed a yellowish film emerging from the mantle groove full of shining dots; farther away from the groove the pellicle held scattered spherules and overlay nascent shell made up of compacted spherites aggregating into a layer.

This is in harmony with the accepted view that the periostracum is secreted out of the mantle groove and then reinforced from below by lime secretions that go to make up the deeper layer of the shell to be eventually reinforced by coloring matter and secretions from the parts of the mantle more remote from the mantle groove.

While in restoration of pieces of shell at the aperture the mantle acts as it did before, this repetition is local for each injured part and does not involve the mantle elsewhere; thus while in normal growth all the mantle margin is simultaneously active, in repair of local defects much of the mantle is inhibited while certain regions only are active. Only when the defects are built up to the former edge level does the entire front advance in normal addition to the entire edge of the shell, step by step with lines of growth showing rhythmic advance and stoppages.

The greatest advance of normal shell beyond the replaced triangular defects was four to five millimeters in four months, see Fig. 1, where the transverse lines indicate new shell out beyond the replaced triangular areas. This is preceded by the above change in coordination of adjacent parts of the mantle margin so that, apparently, the normal growth is repeated only locally just where needed to replace the lost shell; there only the mantle groove arouses to activity and there only the mantle secretes lime and pigment which seems to be in a colloidal matrix in which the pigment does not widely diffuse but remains properly placed to continue the normal color pattern of the shell. Restoration of the equatorial band advanced more rapidly than that of the upper and lower bands where dark coloring matter was slow to appear.

While the white equatorial band is directly continued in the new growths, there are cases in which it is faulted upward nearly one-half millimeter as if the mantle had been held contracted toward the apex of the shell. Also in a red shell the first restored part may be white, later on yellow and finally red; thus leaving a pale scar to show the imperfection of the first part restored.

When, by accident, one snail had its shell so completely broken that it was removed entirely, the snail lived on three days and crawled about, though gradually dwindling in size though in moist air. Here a new shell was started in form of wax-like secretion film, covering most of the body except the lungs and the left retractor muscle. This film started in the mantle groove, ran back over the velvety and white zones and thence over the body. Blister areas in this soft membrane gave effervescence with HCl. In water this pellicle peeled off the animal readily.

Such abortive shell making was seen by Techow on removing the shell from 51 *Helix pomatia,* all of which died, though one lingered 27 days without attaining any real shell.

In addition to real regeneration of marginal injuries to the shell, *Polymita picta* was found able to heal over insular areas (2 x 3 mm.) where the shell was removed on the first quarter of the last whorl by a delicate pellicle filled with minute granules crowding together to form an icy sheet. But death prevented

the perfection of this cicatrix as a firm cement. Yet in one case still living such a hole made at the end of the first whorl was in a few days covered over by a thin hard sheet completely healing the wound in the shell, though as yet too brittle to be of great protection.

ON THE SONORAN SIDE OF THE GULF

BY H. N. LOWE

(Concluded from Page 4)

One afternoon without a breath of wind, a heavy ground swell set in, and by night quite a blow from the southwest. By next day the rocks were swept clean of the olive green algae and the *Trivia* and *Crassispira* had to seek refuge under the rocks. The sand beach for miles was covered with acres of algae at high tide line.

The second afternoon after the storm, I was walking the beach about two miles from camp. Just beyond the acres of algae which contained only an occasional stranded *Aplysia californica,* oozing out its purple dye, there was a narrow strip of tide wash, not over fifty yards in extent, of fragments of ascidians, sponges, and corallines, in this I took about forty fine living specimens of a *Lamellaria* unknown to me; different colored animal from *L. diegensis* and higher spired shell than *L. stearnsi.* The mantle entirely covered the thin translucent shell and could only be removed by cutting across the back with a safety-razor blade.

As I expected, this was a chance of a lifetime, for next afternoon tide all had been either taken back into the sea or ground to fragments in the sand after the storm, for several miles this beach was almost unrecognizable; the rock ledges which had teemed with sea life were covered deep with sand and the intervening places where the sand had been were left bare showing the underlying fossiliferous rock.

One afternoon just as the tide was starting out, we heard a great commotion near the shore. It was a huge school of several thousand *corbina* (a game fish about three feet in length), pursuing a vast number of sardines, anchovies, &c. The pursuers drove their prey into our little cove, where they simply went